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Project Summary

Soil-Gas and Geophysical Techniques for Detection of Subsurface Organic Contamination

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From 1985 through 1987, the Air Force Engineering and Services Center (AFESC) funded research at the U.S. Environmental Protection Agency (EPA) Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV) through an interagency agreement. This agreement provided for investigations of subsurface contamination at Air Force Installation Restoration Program sites. The purpose of these investigations was to demonstrate and evaluate inexpensive and relatively rapid reconnaissance techniques which can detect and map subsurface organic contamination. This information can reduce the number and improve the placement of wells required in an investigation, resulting in significant savings in terms of costs and time.

The methods chosen for demonstrations included active and passive soil-gas sampling and analysis, and the geophysical techniques of electromagnetic induction (EM), and d.c. resistivity. Field studies were performed at four Air Force Bases: active soil-gas measurements were performed at all sites; d.c. resistivity and EM measurements were performed at three sites; and passive soil-gas sampling was performed at two sites. The techniques of ground-penetrating radar and complex resistivity were included in the evaluations using experiences at other locations. Based on this limited set of cases and information from published literature, general guidelines on the application of these techniques for detecting organic contamination were developed.

The active soil-gas sampling technique successfully mapped solvents, gasoline, and JP-4 contamination at the four bases where it was used. The passive soil-gas technique was successful in some cases, but not as successful as the active technique, and further research on the performance of the technique is recommended before the method is used widely. The geophysical methods were successful for site characterization, but the EM and d.c. resistivity techniques did not detect gasoline and jet fuel number 4 (JP-4) contamination when it was present. The use of EM and d.c. resistivity for direct detection of hydrocarbons appears to be a subtle technique which depends on a thorough understanding of background information at the site, the skill of the instrument operator, and may depend on the length of time the spill has been present. The ground-penetrating radar and complex resistivity techniques were used successfully at a number of locations for detecting organic contamination. This work was conducted from January 1985 to October 1987.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully

documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

In 1984, the U.S. Environmental Protection Agency (EPA) Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV) and the Air Force Engineering and Services Center (AFESC) entered into an interagency agreement concerning investigations of subsurface contamination at Air Force Installation Restoration Program (IRP) sites. Organic contamination was emphasized in these studies. The traditional approach to these site investigations involves the installation of wells and analysis of ground-water samples. This approach provides a direct measurement of the contamination at the locations sampled. However, information about the extent and degree of contamination may be limited by the number, cost and possible locations of the wells. If inexpensive, and relatively rapid reconnaissance techniques could be used as an aid to selecting the well locations, the number of wells could be reduced. This would save money and time.

The interagency agreement initiated studies at four IRP sites to demonstrate indirect methods for detecting and mapping organic contamination in ground-water and soil. The methods chosen for evaluation were soil-gas and geophysical measurements. These measurement results then were compared to ground water data obtained during the same study. This made it possible to evaluate the performance of the soil-gas and geophysical techniques. However, because of the wide variety in contaminants and geological conditions, care must be used when applying the conclusions developed from these site-specific studies to other locations. To help to extend the results from these studies to other site conditions, additional examples were assembled from the literature. Using all this information, general guidelines were developed for the use of these techniques in investigations of organic contamination of soil and ground water.

Approach

The overall approach to the project was divided into two parts with activities in each proceeding concurrently. These parts consisted of working with a panel of experts to broaden the ideas, approaches and experiences being used as a basis for developing the guidelines; and performing site investigations to demonstrate the soil-gas and geophysical techniques. The Air Force Bases (AFBs) selected are listed in Table 1. Each AFB provides differing geology, climate, depth to water table, and contaminants, thus representing a variety of situations for performing the comparisons.

This series of studies was intended to help formulate a hierarchy of techniques which could be logically adapted and applied to detect contamination for a variety of site conditions. However, the results from the field studies fit better into a framework of broad guidelines rather than into a detailed strategy which ranks techniques.

Field Study Results

The methods chosen for demonstrations included active and passive soil-gas sampling and analysis, and the geophysical techniques of EM and d.c. resistivity. Active soil-gas measurements were performed at all sites; resistivity and EM measurements were performed at three sites; and passive soil-gas sampling was performed at two sites. Key results from these investigations are summarized in Table 2.

The active soil-gas sampling technique successfully mapped solvents, gasoline, and JP-4 contamination at all four bases where it was used. Results from Robins AFB demonstrated that the choice of sampling depth can influence the measurements obtained. At this AFB, initial sampling at 1 meter revealed very little contamination as shown in Figure 1, while additional sampling at 2 meters located more contamination, which is shown in Figure 2 Thus, it is important to perform depth profiles at a number of locations during the initial phase of a study, preferably in regions of known (quantified) ground-water contamination, in order to select the sampling depth. Sampling depth is particularly important at sites where relatively old fuel spills have occurred, because chemical or biological oxidation of the petroleum hydrocarbons can remove fuel constituents from the aerobic soil horizons. The real-time nature of this method also represents a significant advantage over more time-consuming techniques since the choice and number of sampling locations can be evaluated as data are obtained.

Two of the sites investigated with active soil-gas techniques were also investigated by a passive technique which used adsorbent charcoal badges. At these sites, tests were performed to determine the feasibility of mapping the contamination at these sites by selecting the best exposure times for the badges. Performing feasibility tests with the badges was demonstrated to be very important; an insufficient exposure time may indicate an area is uncontaminated when contamination actually is present Alternately, overexposure of the badges may result in saturation of the sorbent which would mask any relative differences in soil-gas contamination at the various sampling locations. This passive soil-gas technique was not as successful as the active technique in detecting contaminated ground water However, contaminated areas were identified successfully in some cases. Further testing of the performance of this technique for a variety of contaminants and geologic conditions is recommended before the method is used widely. If on-site personnel are available to conduct the sampling, the low analytical cost of this method has potential for reducing site investigation costs in some cases.

The geophysical methods were successful for site characterization, but the EM and d.c. resistivity techniques did not detect gasoline and JP-4 contamination when it was present. This was attributed to the natural variations in background

Table 1. *Geology, Climate, and Contaminants at Air Force Base Study Sites*

Base	Geology	Climate	Contaminant
Holloman AFB	sand, interbedded clay	arid	gasoline, JP-4, solvents
Phelps Collins ANGTB	karst	humid	solvent, JP-4, buried metallic objects
Robins AFB	marine sand	humid	JP-4, solvents
Tinker AFB	clay	humid	JP-4

Table 2. Key Results from the AFB Investigations

Site and contaminants	Method	Comment
Holloman AFB, BX Service Station, Gasoline	Active soil-gas sampling	Compares favorably with ground-water data. Demonstrates movement of contaminants along utility corridors.
	EM, d.c. resistivity	Do not detect organics because of natural variability in soil resistivity. Culture limited extent of survey.
Robins AFB,JP-4 Spill, JP-4	Active soil-gas sampling	Compares favorably with ground-water data in spite of 20-year age of spill. Demonstrates importance of depth of sampling.
	Passive soil-gas sampling	Preliminary test has mixed results compared to ground-water data.
	EM, d.c. resistivity	Do not detect organics because of natural variability in soil resistivity due to rainfall effects and culture. AFB radar interferes with EM-34 measurements..
Tinker AFB, Fuel Farm 290, JP-4	Active soil-gas sampling	Compares favorably with ground-water data; technique effective in clay soil
	Passive soil-gas sampling	Preliminary test has mixed results compared to ground-water data. Technique may be responding to surface contamination at times.
	EM, d.c. resistivity, complex resistivity	Were not attempted due to high density of buried pipes and tanks, and fences and pipes on surface.

resistivity which masked any resistivity anomaly due to the presence of hydrocarbons. Based on these results, the use of EM and d.c. resistivity for direct detection of hydrocarbons appears to be a subtle technique which depends on a thorough understanding of background information at the site, the skill of the instrument operator, and may depend on the length of time the spill has been present. This does not preclude the use of these techniques in site characterization. The techniques of GPR and complex resistivity were not demonstrated at the AFBs, but their successful performance in detecting hydrocarbons has been documented in the literature. Table 3 summarizes the general recommendations for application of the geophysical techniques.

Note that only two techniques, GPR and complex resistivity, are recommended for routine use in detecting organic contamination. GPR is commercially available. Complex resistivity, however, is the subject of several research efforts, and is not widely available. The d.c. resistivity and EM techniques may sometimes be useful at a site for detection of hydrocarbons, but the conditions for which this is true are not now understood. Other techniques with greater likelihood of success should be considered first.

Fundamentals for Planning Site Investigations

To place these results in context, recommendations for planning a site investigation also are presented. These recommendations were prepared in conjunction with members of the panel of experts assembled to provide advice to the project. The recommendations address general considerations in designing an investigation, provide examples and references to similar cases in the literature, list the steps in planning a soil-gas investigation, and list issues to be considered in planning a geophysical investigation. The issues which should be considered are presented in series of questions organized by topic area, including hydrology, the use of isotopes, and water chemistry.

Conclusions

Demonstrations of soil-gas and geophysical techniques at four AFBs provided the basis for the development of broad guidelines for the application of these methods. The active soil-gas sampling technique successfully mapped solvents, gasoline, and JP-4 contamination at the bases. The passive soil-gas technique was successful in some cases, but not as successful as the active technique, and further research on the performance of the technique is recommended before the method is used widely. The geophysical methods were successful for site characterization, but the EM and d.c. resistivity techniques did not detect gasoline and jet fuel number 4 (JP-4) contamination when it was present The use of EM and d.c. resistivity for direct detection of hydrocarbons appears to be a subtle technique which may sometimes be useful at a site for the detection of hydrocarbons, but the reasons for this are not well understood. Other techniques with greater likelihood of success should be considered first. The ground-penetrating radar and complex resistivity techniques have been used successfully at a number of locations for detecting organic contamination.

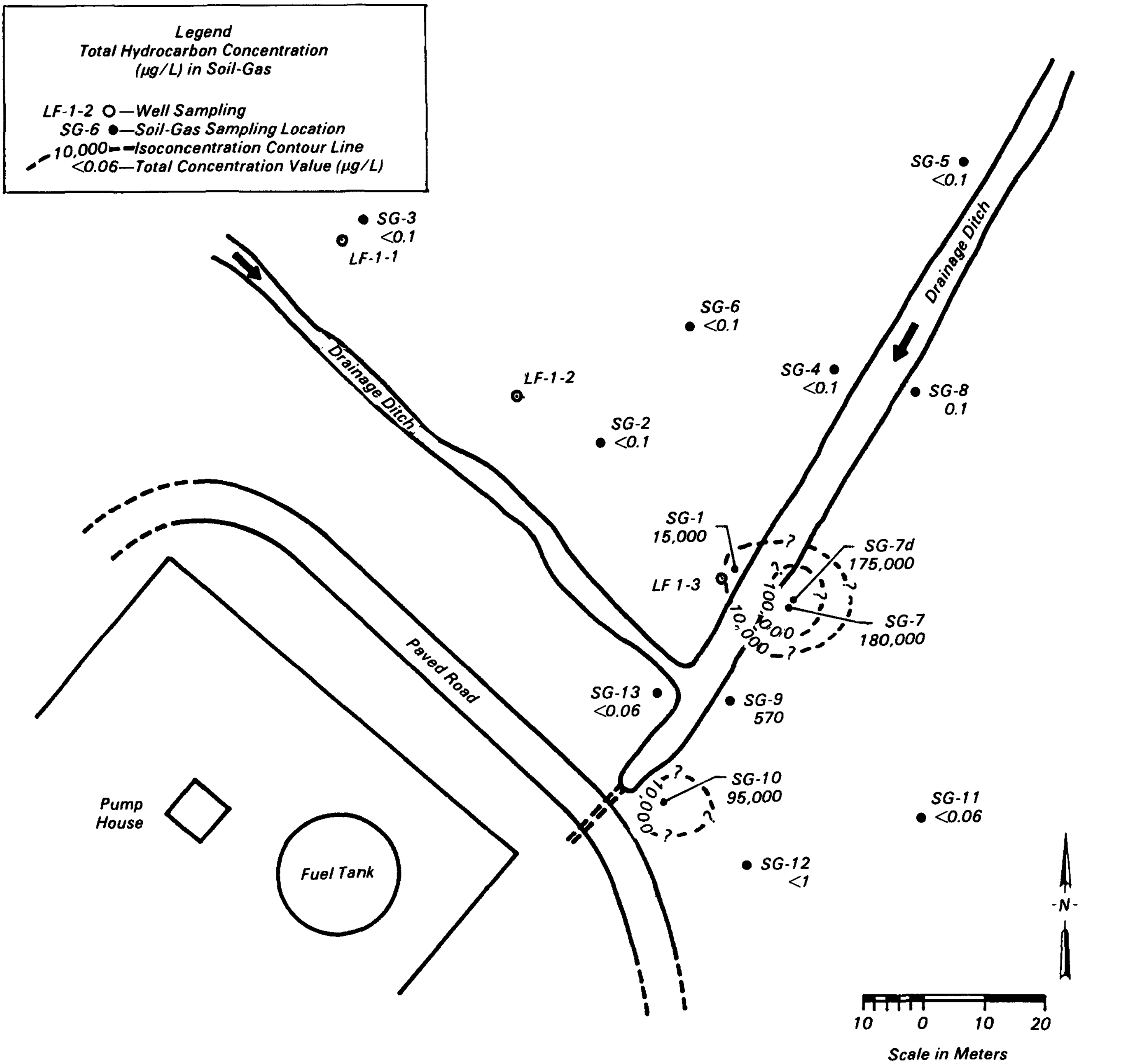

Figure 1. Concentrations of total hydrocarbons in soil gas at JP-4 spill site, Robins AFB. Sampling depth: 1 meter.

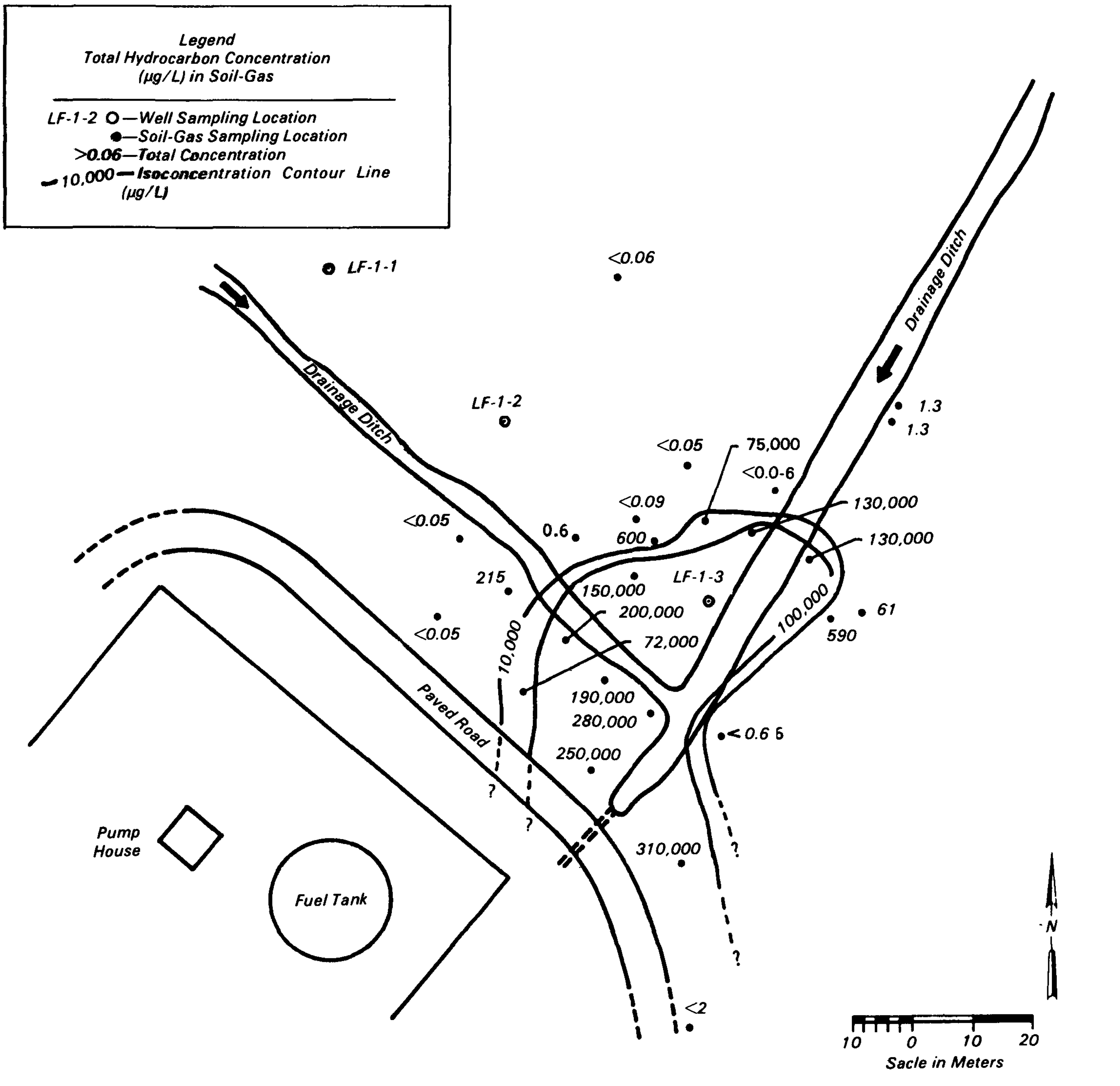

Figure 2. *Concentrations of total hydrocarbons in soil gas at JP-4 spill site, Robins AFB. Sampling depth: 2 meters.*

Table 3. *Generalized Applications of Geophysical Techniques*

Technique	Application: Site Characterization	Conductive Leachate*	Metal Objects*	Organic Contamination
Ground Penetrating Radar (GPR)	yes	yes	yes	yes
Electromagnetics (EM)	yes	yes	yes	possibly
D.C. Resistivity	yes	yes	yes	possibly
Complex Resistivity	yes**	yes**	yes**	yes
Seismic Refraction	yes	no	no	no
Metal Detector	no	no	yes	no
Magnetometer	no	no	yes***	no

*In some cases, the organic contamination will be associated with inorganic contamination; examples include organics in metal drums and mixed organic-inorganic leachate plumes.
**But d.c. resistivity is equally good and much cheaper.
***Ferrous metals only.

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***Aldo T. Mazzella** is also the EPA Project Officer (see below).*
The complete report, entitled "Soil-Gas and Geophysical Techniques for Detection of Subsurface Organic Contamination," (Order No. PB 88-208 194/AS; Cost: $14.95, subject to change) will be available only from:
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